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# Destructive Single-Event Failures in Schottky Diodes

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# List of Acronyms

- DUT – Device Under Test
- EEE Parts – Electrical, electronic, and electromechanical parts
- EEE-INST-002 – Instructions for EEE Parts Selection, Screening, Qualification, and Derating
- GSFC – Goddard Space Flight Center
- IEEE – Institute of Electrical and Electronics Engineers
- $I_R$ – Reverse Current
- IR – International Rectifier
- LBNL – Lawrence Berkeley National Laboratory Facility's 88-Inch Cyclotron
- LET – Linear Energy Transfer
- MOSFET – Metal-oxide-semiconductor field-effect transistor
- NEPP – NASA Electronic Parts and Packaging program
- NSREC – Nuclear and Space Radiation Effects Conference
- REDW – IEEE Radiation Effects Data Workshop
- SEE – Single-Event Effect
- STMicro – STMicroelectronics
- TAMU – Texas A&M University's Radiation Effects Facility
- $V_R$ – Reverse Voltage
- $V_F$ – Forward Voltage

# Outline

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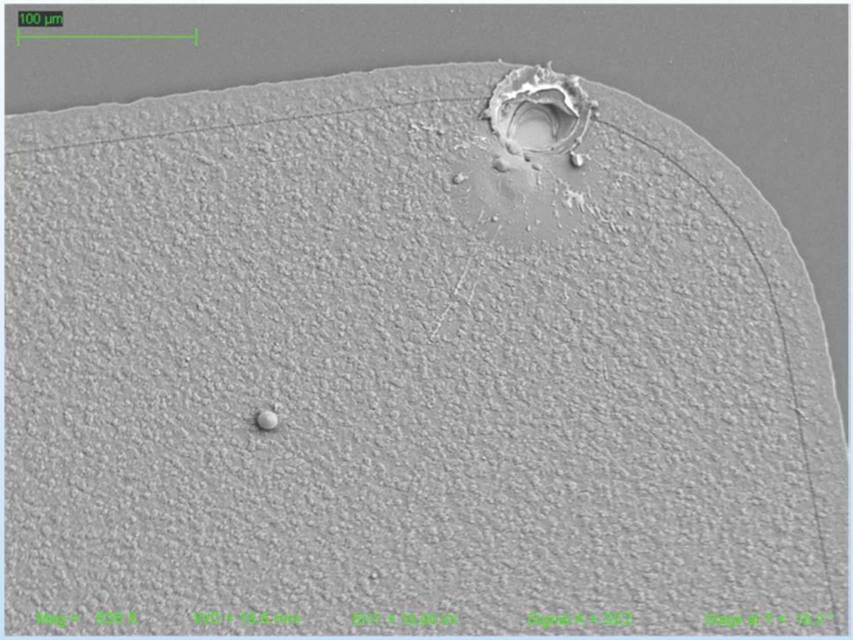
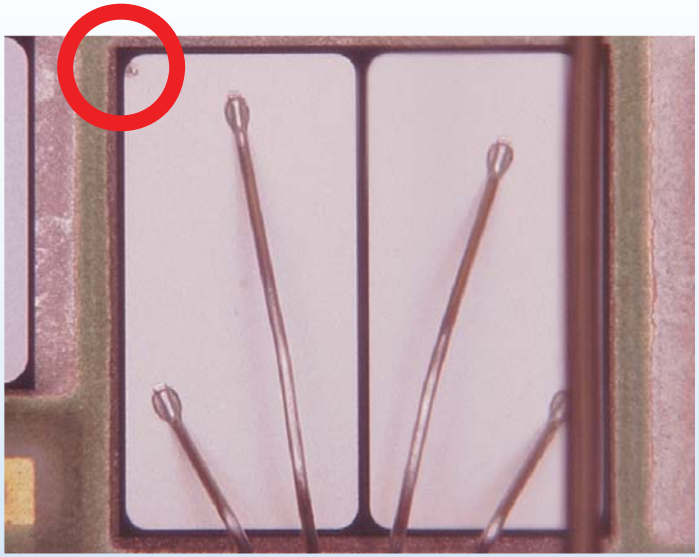



M. V. O'Bryan, *et al.*, *IEEE REDW*, 2012.

# Introduction: Destructive Failures in DC-DC Converters

- **Destructive SEEs observed in DC-DC converters by two different manufacturers, IR and Crane Aerospace**
  - **Attributed to the shorting of the anode and the cathode of the output diodes**
- **Diodes generally are not considered to be susceptible to SEEs**
  - **Implication of these diode failures could be catastrophic to scientific instruments, or even entire spacecraft**
- **Under NEPP, the diodes are independently irradiated to identify and understand the failure mechanism, and the severity of the potential impact to NASA missions**



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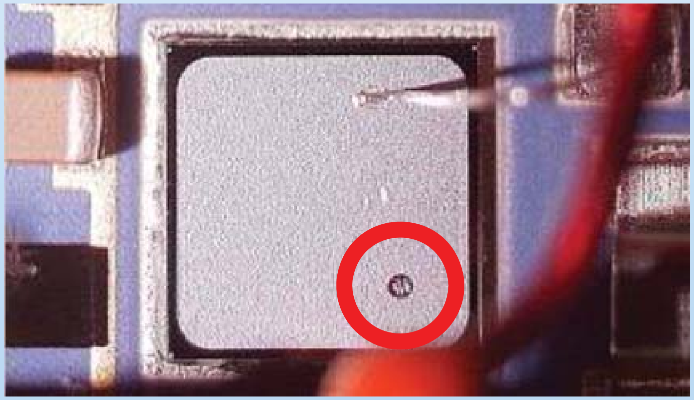

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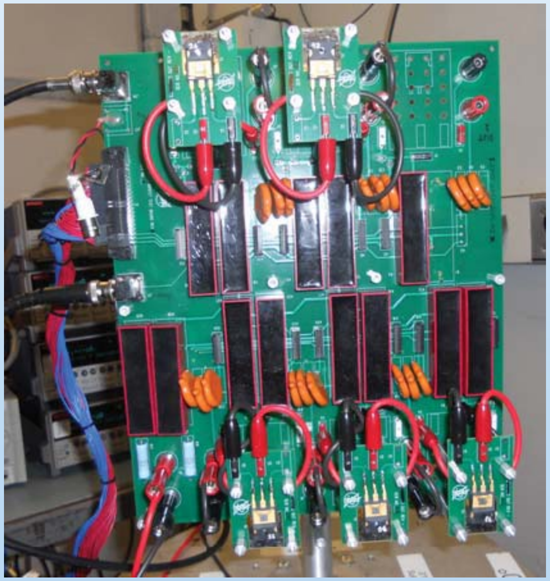
# Parts Tested and Test Set-Up

- **Diodes Tested**
  - **ON Semiconductor MBR20200CT**
    - **Dual 200 V, 10 A Schottky diode**
    - **45 diodes were irradiated**
  - **Equivalent to Sensitron SD125SB45A**
    - **45 V, 15 A Schottky diode**
    - **4 diodes were irradiated**
  - **ST Micro STPS20100**
    - **Dual 100 V, 10 A Schottky diode**
    - **3 diodes were irradiated**

- **Test Set-Up**
  - **Experiments were conducted using GSFC High-Voltage Power MOSFET Motherboard**



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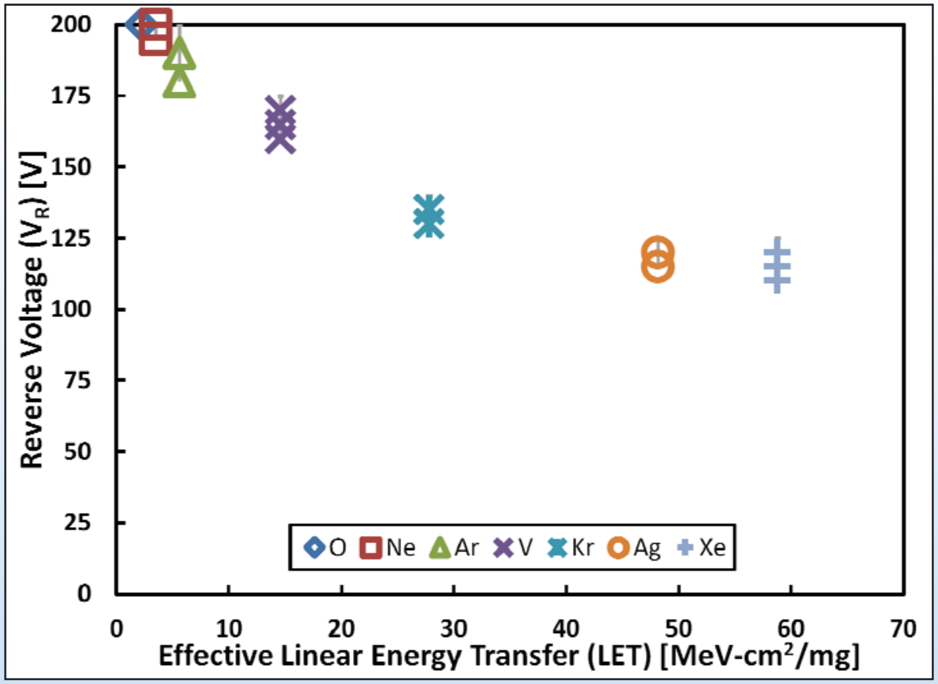
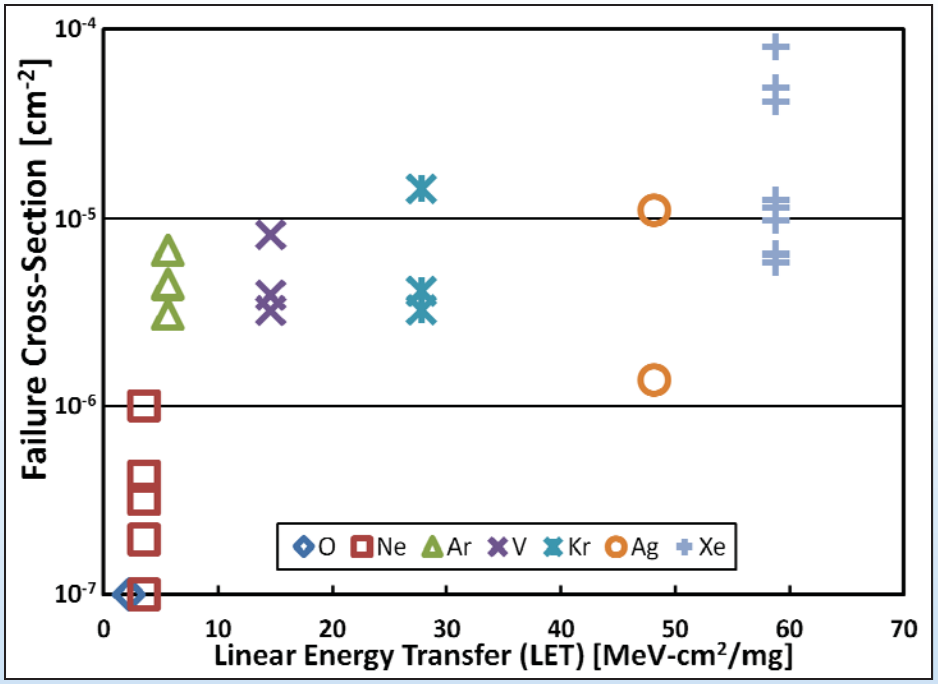
# Test Facilities and Beam Conditions

| Facility | Ion | Energy (MeV) | LET at Normal Incidence (MeV-cm$^2$/mg) | Range in Si (µm) |
|---|---|---|---|---|
| TAMU | Ar | 944 | 5.60 | 193 |
| | Kr | 1032 | 27.80 | 170 |
| | Xe | 1512 | 51.5 | 120 |
| | Ta | 2076 | 77.3 | 119 |
| LBNL | O | 183 | 2.19 | 226 |
| | Ne | 216 | 3.49 | 175 |
| | V | 508 | 14.59 | 113 |
| | Ag | 10 | 48.15 | 90 |
| | Xe | 1232 | 58.78 | 90 |

# Test Results

## ON Semiconductor MBR20200CT




- All parts were only found to be susceptible when reverse biased
- EEE-INST-002 states that all diodes should be derated to 75% of rated voltage, so in theory, these diodes could be used up to a voltage of 150 V
- When irradiated with 508 MeV V, failed at voltages greater than 150 V
- When irradiated with 1032 MeV Kr, failed below derated voltage threshold

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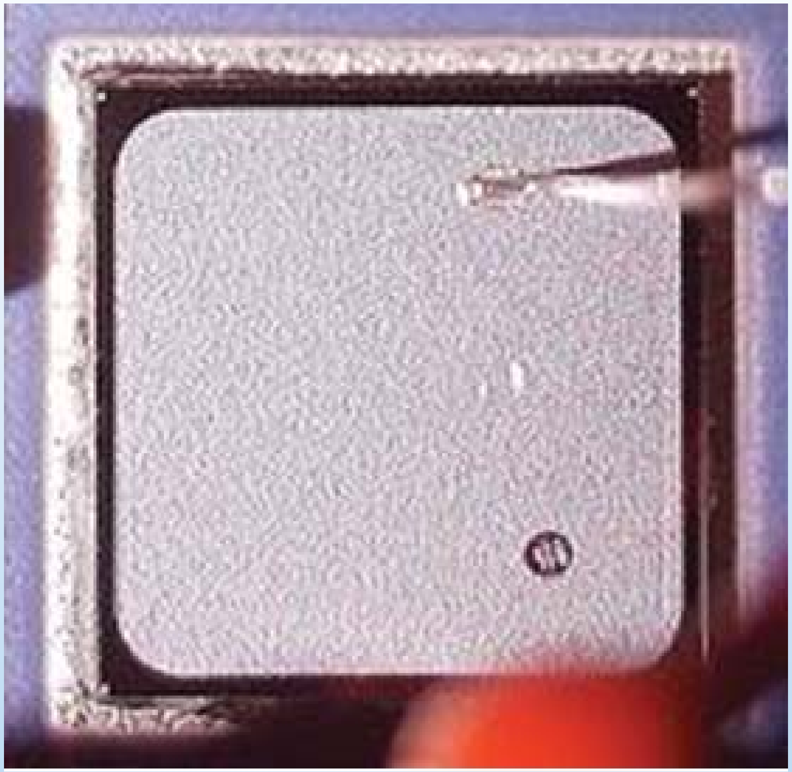
# Test Results

## Sensitron SD125SB45A

- Schottky diodes were irradiated with 1232 MeV Xe (LET = 58.8 MeV-cm$^2$/mg) at LBNL and with 2076 MeV Ta (LET = 77.3 MeV-cm$^2$/mg) at TAMU
  - No failures were observed with either ion, including at full rated voltage of 45 V
- Failure in the MTR28515 may be due to something other than burnout in the diode
  - Location of the failure was not along the guard ring in the DC-DC converter test
  - No failures observed in these parts independent of the converter



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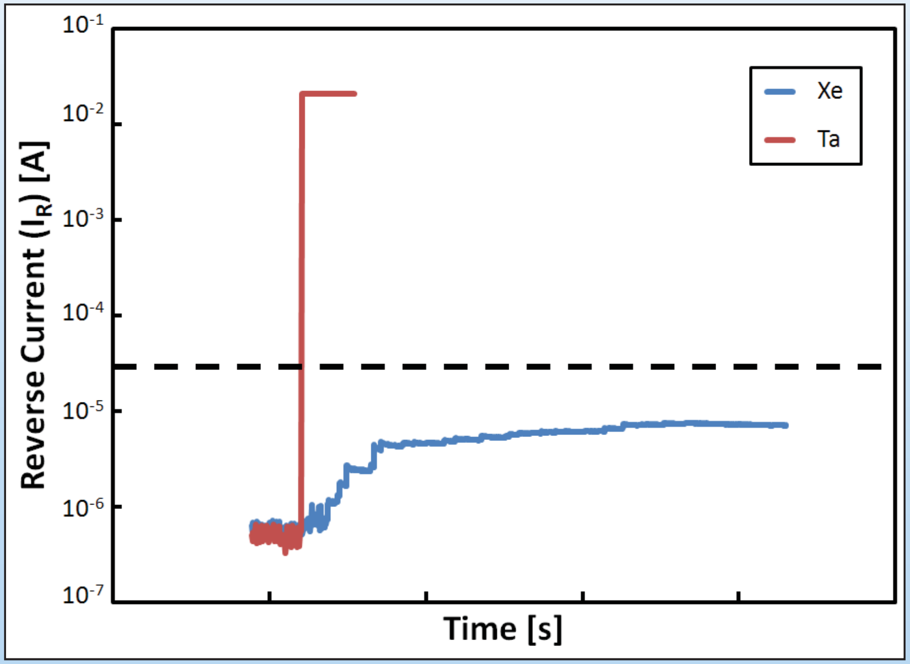
# Test Results
## STMicro STPS20100

- Full rated voltage (100 V) was applied during irradiation
- Current increased in steps during irradiation with Xe, but did not fail
  - May have exceeded datasheet specification for reverse current (30 µA) if fluence had been higher (3x10$^5$ particles/cm$^2$)
- Diode failed short as soon as the beam was turned on with Ta
  - Failure rate would be very low



# Additional Parts Tested

| Manufacturer | Part Number | Reverse Voltage (V) | Number of Parts Tested (#) | Xe Energy (MeV) | Xe LET ($MeV\text{-}cm^2/mg$) |
|---|---|---|---|---|---|
| STMicro | 1N5819 | 45 | 3 | 1512 | 51.5 |
| | STPS1045 | 45 | 3 | 1512 | 51.5 |
| IR/Vishay | 95-9951 | 45 | 3 | 1366 | 53.1 |
| | 96-1063 | 45 | 4 | 1366 | 53.1 |
| | 96-1052 | 60 | 3 | 1366 | 53.1 |
| | 95-9953 | 150* | 1 | 1366 | 53.1 |
| | 95-9942 | 150 | 3 | 1366 | 53.1 |

* Part irradiated at 100 V

# Path Forward

- Recently procured 23 different Schottky diodes
  - Variety of manufacturers, reverse voltage ratings, and forward current ratings
- DUTs will be tested at LBNL June 29-July 1
  - 12 hrs to irradiate 46 DUTs
- Test plans are go/no-go testing
  - Will irradiate with Xe at 100% of rated voltage
    - If pass, test two more under same conditions
    - If fail, test at 75%, 50%, 25%...
  - Intent is to identify what parameters determine failure
  - Derating guideline would be next step using failing parts

# Path Forward

## Investigating Effect of Manufacturer
## Investigating Effect of Forward Current
## Investigating Effect of Reverse Voltage

| Part Number | Manufacturer | Reverse Voltage | Forward Current |
|---|---|---|---|
| MBR20200CTTU | Fairchild Semiconductor | 200 | 10 |
| FYPF2010DNTU | Fairchild Semiconductor | 100 | 20 |
| MBR20100CTTU | Fairchild Semiconductor | 100 | 10 |
| MBR2060CT | Fairchild Semiconductor | 60 | 20 |
| MBR3045PT | Fairchild Semiconductor | 45 | 30 |
| FST30100 | Microsemi | 100 | 15 |
| NXPS20H100CX,127 | NXP Semiconductor | 100 | 10 |
| MBRF20100CTG | ON Semiconductor | 100 | 10 |
| MBR2080CTG | ON Semiconductor | 80 | 10 |
| MBR2060CTG | ON Semiconductor | 60 | 10 |
| MBR6045WTG | ON Semiconductor | 45 | 30 |
| MBR4045WTG | ON Semiconductor | 45 | 20 |
| MBRF2045CTG | ON Semiconductor | 45 | 10 |
| RB205T-60 | Rohm Semiconductor | 60 | 7.5 |
| STPS60SM200CW | STMicroelectronics | 200 | 60 |
| STPS20200CT | STMicroelectronics | 200 | 10 |
| STPS30H100CT | STMicroelectronics | 100 | 15 |
| STPS40M60CT | STMicroelectronics | 60 | 20 |
| STPS4045CT | STMicroelectronics | 45 | 20 |
| MBR20H200CT-E3/45 | Vishay Semiconductor | 200 | 10 |
| MBR60100CT-E3/45 | Vishay Semiconductor | 100 | 30 |
| MBR20100CT-E3/4W | Vishay Semiconductor | 100 | 10 |
| VS-MBR4045WTPBF | Vishay Semiconductor | 45 | 20 |



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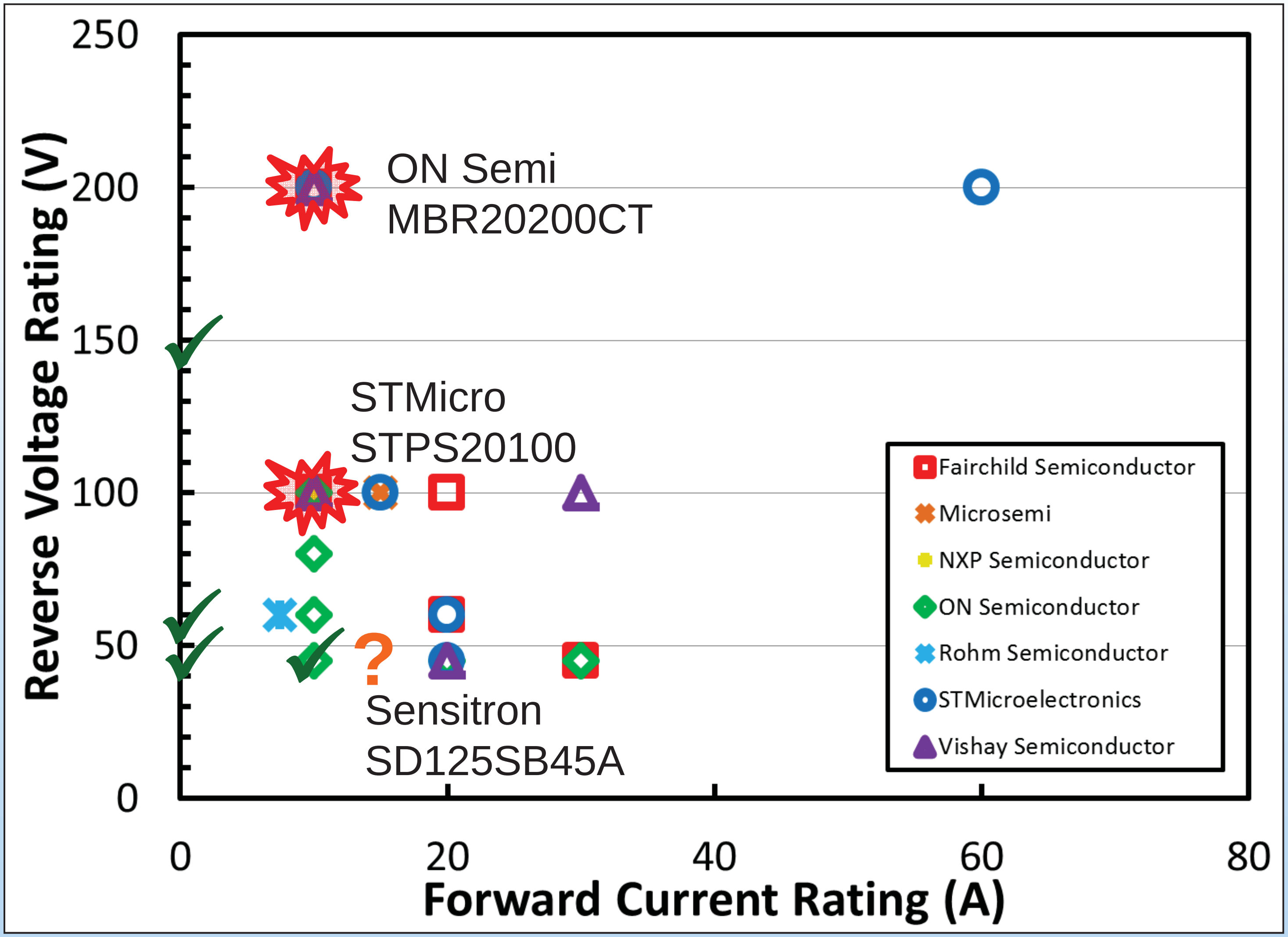
# Path Forward



# Conclusions

- We have shown that Schottky diodes are susceptible to destructive single-event effects
  - Failures only occur when diodes are reverse biased
  - Failures visible along guard ring in parts with no current limiting
- Future work will be completed to identify parameter that determines diode susceptibility
  - Manufacturer(s)? Reverse voltage? Forward Current?
- By determining the last passing voltages, a safe operating area can be derived
  - If these values are used for derating, rather than the rated voltage we can work to ensure the safety of future missions
    - This is currently done with power MOSFETs